UNIVERSITY of GREENWICH

DATA CAPTURE METHODOLOGIES FOR HERITAGE-BIM
A LITERATURE RTEVIEW

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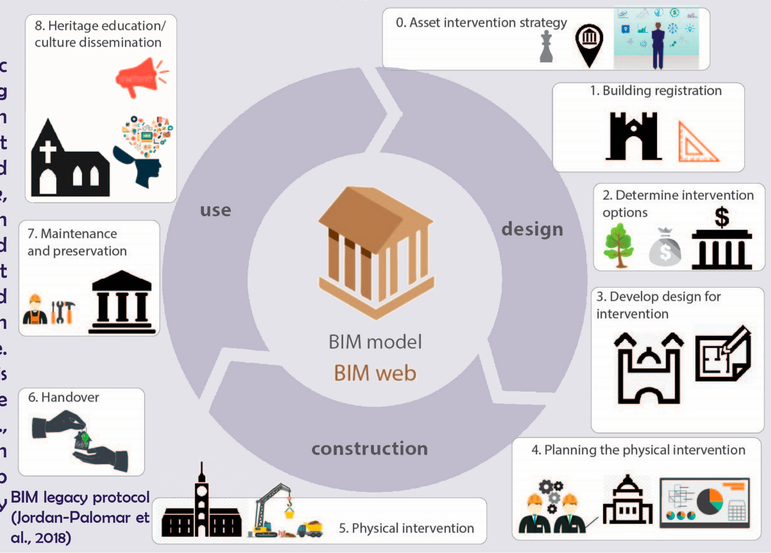
H-BIM

Heritage Building Information Modelling (HBIM) is defined by Historic England, (2017) as "a multi-disciplinary process that requires the input and collaboration of professionals with very different skillsets.". HBIM combines multi-dimensional visualization with comprehensive, parametric databases. It allows to integrate management of graphical and informational data flows. to facilitate collaborative developing the strategy of building project design, construction and facility management among project partners (Fai et al., 2011). It helps to transform individual executors into teams and decentralise tools into complex solutions, this leads to individual tasks being implemented as complex processes; perform life cycle operations of a construction project more effective, faster and with lower cost (Logothetis, Delinasiou and Stylianidis, 2015).

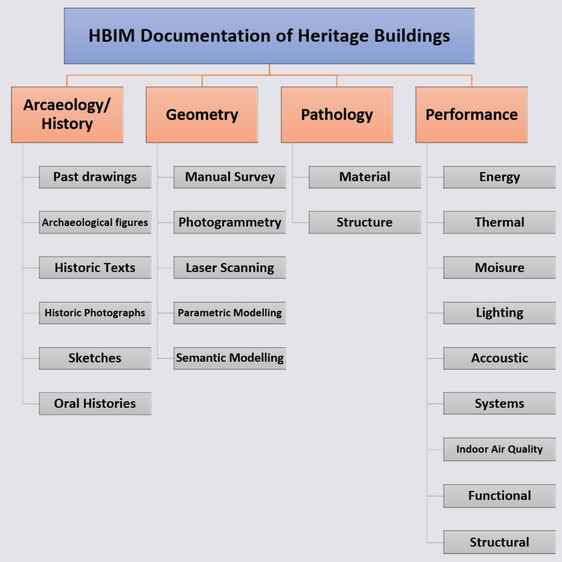
HBIM can represent many advantages to historic buildings. The main advantages of modelling historical buildings are in the integrity of design and visualisation, cost estimation, conflict detection, full planning implementation and improved stakeholder collaboration (Volk, Stengel and Schultmann, 2014). It can also help in automatic measurement, identification and modelling of damaged or non-existent architectural elements (Koller, Frischer and Humphreys, 2009), so, it can be a representation of the historic building's changes over time. Moreover, one of the major benefits of H-BIM is the transmissibility of the information during the life cycle of the heritage building (Banfi et al., 2017). HBIM also can represent a contribution towards energy analysis and economic analysis up to multi-thematic analysis within sustainability (Azhar et al., 2011) (Habibi, 2017).



BIM legacy protocol (Jordan-Palomar et al., 2018)

HBIM and the Documentation of Heritage Buildings

In the heritage buildings' sector many challenges are facing the implementation of BIM tools, such as the inevitability of starting at an intermediate point in the asset's life cycle, which can be much more complex than the relatively straightforward cradle-to-grave model that describes new-build construction (Historic England, 2017). More challenges are present in the processing of historic buildings: irregular geometry, non-homogeneous materials, variable morphology, not documented changes, damage and various stages of construction (Barazzetti and Banfi, 2017).



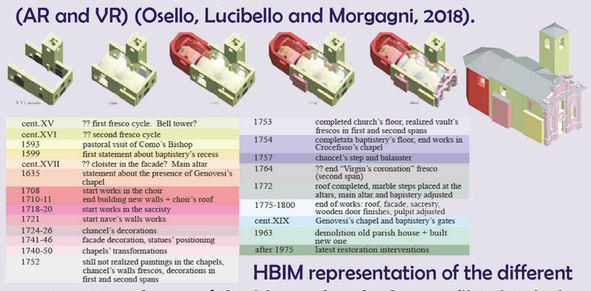
HBIM offers very versatile solutions for modelling and managing information relating to existing and heritage buildings. It can be used as a documentation and management tool. It can also be used as a research tool for documentation and interpretation of historic buildings and representation of its changes over time. HBIM can incorporate both quantitative assets (intelligent objects, performance data) and qualitative assets (historic photographs, oral histories, music) (Fai et al., 2011). It can also include historic texts, archaeological figures, architectural information, administrative data and past drawings, sketches, photos etc. The acquisition of all possible data is the first step to contribute towards fundamental modelling for building recording and documentation (Cheng, Yang and Yen, 2015).

A wide range of data can be of benefit for the process of documentation, modelling and visualisation of heritage buildings, these data (whether tangible; such as the geometry, materials and structural systems, or intangible; such as the historical record of the building, its cultural assets and its performance) can vary in scope, purpose and investigation tools. These different data can be categorised into four main categories, each domain requiring its own documentation and investigation tools: Archaeological and historical data, Geometry, Pathology and Performance.

HBIM DOCUMENTATION OF HERITAGE BUILDINGS

ARCHAEOLOGY/ HISTORY

HBIM offers a process of digitally documenting all the features incorporated into the heritage building over its life-span, thus affords unique opportunities for information preservation (Albourae, Armenakis and Kyan, 2017). HBIM can combine the tangible geometry of the building with many of its intangible aspects such as historic architectural drawings, historic texts, archaeological figures, architectural information, sketches, photos etc. These data sources can create a better understanding about the building and its historic morphology over time. They can also contribute towards understanding the construction systems of the building and its development over time, also to build an idea about the materials and technologies used in its construction. This can be also used to disseminate the building and its historic development for the wider audience through modelling the different phases of the building's history. In this sense, more advanced visualization and presentation can be achieved using augmented and virtual reality techniques (AR and VR) (Osello, Lucibello and Morgagni, 2018).



cent.XV	?? first fresco cycle. Bell tower?	1753	completed church's floor, realized vault's frescos in first and second spans
cent.XVI	?? second fresco cycle	1754	completata battistery's floor, end works in Crocefisso's chapel
1593	pastoral visit of Como's Bishop	1757	chancel's step and balauster
1599	first statement about baptistery's recess	1764	?? end "Virgin's coronation" fresco (second span)
cent.XVII	?? cloister in the facade? Main altar	1772	roof completed, marble steps placed at the altars, main altar and bapistery adjusted
1635	statement about the presence of Genovesi's chapel	1775-1800	end of works: roof, facade, sacresty, wooden door finishes, pulpit adjusted
1708	start works in the choir	cent.XIX	Genovesi's chapel and baptistery's gates
1710-11	end building new walls + choir's roof	1963	demolition old parish house + built new one
1718-20	start works in the sacristy	after 1975	latest restoration interventions
1721	start nave's walls works		
1724-26	chancel's decorations		
1741-46	facade decoration, statues' positioning		
1740-50	chapels' transformations		
1752	still not realized paintings in the chapels, chancel's walls frescos, decorations in first and second spans		

HBIM representation of the different constructive phases of St. Maria church, Scaria d'Intelvi, Italy and its historical transformation. (Brumana et al., 2013)

GEOMETRY

Knowledge of the position, size, shape and identity of the components of a historic building or site is a fundamental part of a project related to the conservation of cultural heritage (Historic England, 2018). Geometry capturing of heritage buildings into HBIM platforms is a very challenging process due to the irregular geometry, non-homogeneous materials, variable morphology, not documented changes, damage and various stages of construction that typically characterises heritage buildings.

HBIM documentation and representation of heritage buildings can be carried out using different techniques with a wide range of accuracy, cost efficiency, time consumption and technologies. A range of techniques can be used from traditional surveying techniques to photogrammetry to laser scanning.

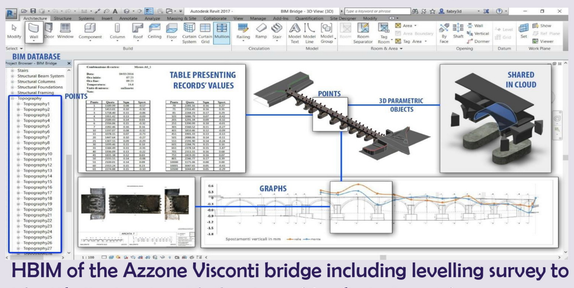
TRADITIONAL SURVEY

Hand measurements is the least expensive option to record the geometry of a building. It can provide dimensions and relative positions of small and less complicated objects, but they can become less accurate and uneconomic for larger objects.
Total station theodolites (TSTs) can be used for the collection of data, as well as to survey a site control network, which is usually the first step to precisely identify the scanning points for other survey techniques (Historic England, 2018).

PATHOLOGY

Investigating and documenting the pathology of heritage buildings has a significant impact on the decisions of its conservation, retrofitting and management. Pathological investigations focus on studying the quality of the materials and structural system of the building, they also study original materials and construction methods, material degradation, historic fabric developments (Historic England, 2017) and structural decay. Therefore, pathological investigation can be categorised into material pathology and structural pathology.

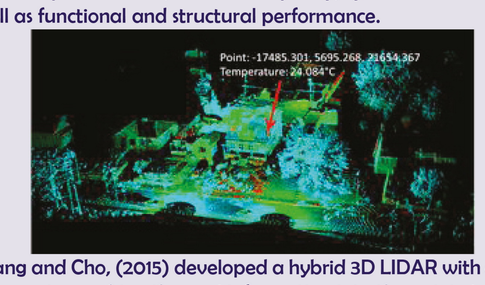
Using thermal imagery to identify the structure system, different materials and thermal bridges. (Stober et al., 2018)



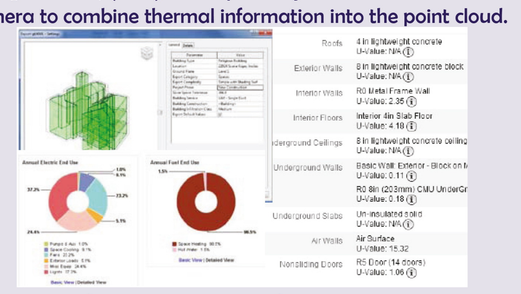
HBIM of the Azzone Visconti bridge including levelling survey to identify its structural behaviour. (Banfi et al., 2017)

PERFORMANCE

Documentation and integration of the building performance is a major contribution of HBIM towards the decisions of design, retrofitting and management of the heritage building. Building performance can represent many aspects such as energy performance, thermal performance, visual performance, acoustic performance, indoor air quality, systems efficiency, as well as functional and structural performance.



Wang and Cho, (2015) developed a hybrid 3D LIDAR with an IR camera to combine thermal information into the point cloud.

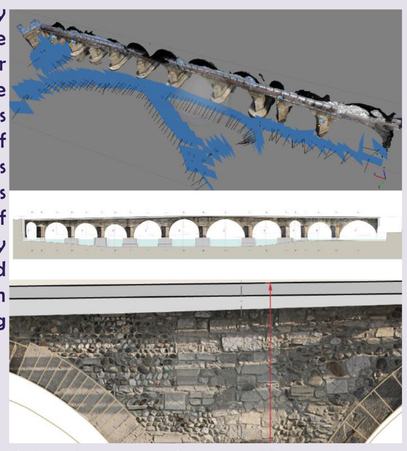


Building Performance Analysis of St. Maria church, Scaria d'Intelvi, Italy . (Brumana et al., 2017)

PHOTOGRAMMETRY

Photogrammetry is the determination of accurate measurements and three-dimensional data from photographs (Matthews, 2008). It is based on using images taken at different viewpoints to record the 3D geometry of a building or object (Dore and Murphy, 2017). Photogrammetry includes areal and close-range photogrammetry, which share the same principles of triangulation where lines of sight (rays) from two different camera locations are joined to a common point on the object. the three-dimensional location of the point is determined by the intersection of these rays (Dore and Murphy, 2017).

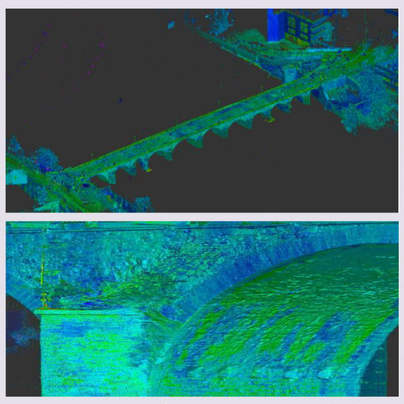
Photogrammetry is less expensive tnan laser scanning, the entire process requires a lot of processing time. Its main advantage is the addition of high-quality imagery and colour information to the resulting data.



Photogrammetry of the elevations of Azzone Visconti bridge. (Banfi et al., 2017)

LASER SCANNING

Laser Scanning is seen as the most accurate and efficient tool in the field of as-built survey and documentation. Laser scanning includes various technologies, range of measurement, accuracy and operation techniques. In terms of technology laser scanners are based on one of three principles: triangulation, pulse (time-of-flight; ToF) or phase-comparison (Historic England, 2018). However, the range and accuracy capabilities from each method vary. Laser scanners can be hand held, backpacks mounted, tripod based, vehicle mounted or airborne (usually referred to as Lidar derived from Light Detection and Ranging). They can vary in range from under a metre to several kilometres and vary in accuracy from a fraction of a millimetre to 300 mm, depending on the site requirements.

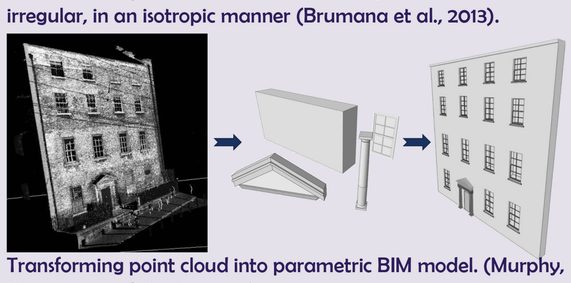


The disadvantage of laser scanning, beside the cost factor, is in the post-processing phase which can be very time and effort consuming. Also, laser scanners are not as flexible as cameras regarding data capture. It can take over an hour at each position.

Laser scanning of Azzone Visconti bridge. (Banfi et al., 2017)

PARAMETRIC MODELLING

The most important part of the process of HBIM is to generate parametric models. The major challenges in modelling historic buildings in HBIM is the lack of pre-defined parametric objects compared to the extensive libraries used to model new buildings. So it is needed to convert the surface of constructed facilities to desired parametric models, that should contemplate about the level of details and simplification of the models suitable for conservation projects. While offering the possibility to modify the parameters of the shape of the elements, in particular, of historical objects that are often irregular, in an isotropic manner (Brumana et al., 2013).

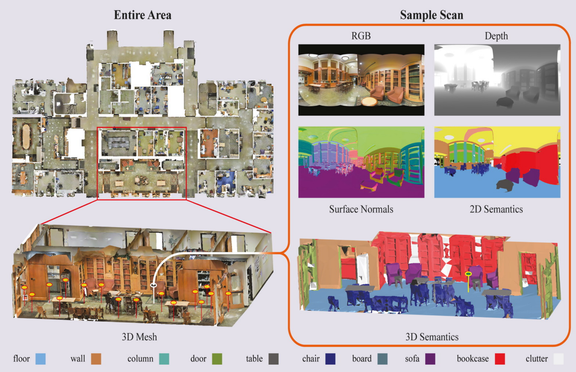


Transforming point cloud into parametric BIM model. (Murphy, Mcgovern and Pavia, 2009)

A model of Liverpool street station, point cloud transformed to parametric objects for the HBIM model. (Historic England, 2017)

SEMANTIC MODELLING

A developing research area in the field of laser scanning is the process of converting point cloud into semantically rich BIM models (Carbonari, 2018). This can be done by creating algorithms that can learn the unique features of different types of surfaces and the contextual relationships between them and uses this knowledge to automatically label patches as walls, ceilings, or floors etc.. (Xiong et al., 2013). This technology, while still in its infancy, has great potentials for facilitating the automated transformation of raw point cloud data into useful semantic BIM models in one step, which can contribute towards time and effort saving. However, a lot of research is still needed in this area.



Producing semantic model from 3d scanning. (Armeni, et al, 2017)

PURPOSE OF THIS RESEARCH

This research is part of a PhD project and the purpose is to categorise different data domains that could be investigated within the process of HBIM documentation of heritage buildings. It aims to review available data capture methodologies for digitally documenting heritage buildings and ascertain which technologies have the most potential for accuracy, time investment, ease of use, cost, and data liveability over time.

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